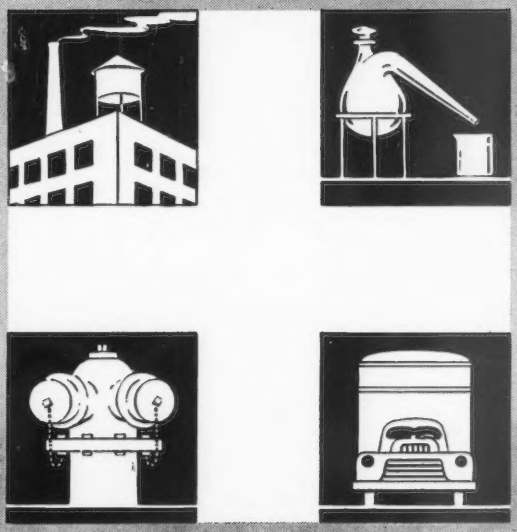
The Journal

OF THE AMERICAN SOCIETY OF SAFETY ENGINEERS



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AMERICAN SOCIETY OF SAFETY ENGINEERS

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AS THIS second issue of the Journal goes to press, we have on hand many complimentary letters on our new publication. We are indeed grateful. We also have received a number of suggestions, which we appreciate especially, for we want to make this publication as useful as possible. One of the suggestions—printing the Safety Engineers' Creed in a manner suitable for framing—you'll find in this issue . . . We're happy, too, that Society membership information in the first issue brought national headquarters some 75 requests for application forms . . . We think we've lined up some fine articles for this issue. We're very proud of the "twins" on the controversial 88:10:2 ratio, by those two prominent safety pioneers, H. W. Heinrich and Roland P. Blake. Mr. Heinrich, whose research and writings have earned him an international reputation, has been a member of our Society since 1924. Mr. Blake, also a member, began his safety career nearly 45 years ago and continues today as consultant for the Bureau of Labor Standards, from which he retired last year as principal safety engineer and chief, Technological Branch.

How Does A Creed Develop? What Can It Mean To Us Personally?

WHAT we believe, deeply and sincerely, we generally try to put into some carefully worded statement which will tell others just what we stand for as a group and as individuals. Often this statement is called a creed.

The members of the American Society of Safety Engineers subscribe to such a statement, the Creed of the Safety Engineer, a formally adopted, individual professional pledge. Some Society chapters use the Creed in ceremonies for the initiation of members and installation of officers. Other chapters give it a much less prominent place in their activities.

But perhaps every safety engineer on occasion has felt a personal need for a tangible expression of his professional attitude. The Creed of the Safety Engineer exists to help fill that need. In answer to a number of requests, it is printed on the inside back cover of this issue of the Journal in a design which, framed and displayed as a certificate, will make an attractive addition to the safety engineer's office wall.

Whether it merely remains on the wall, or instead becomes an important influence in the safety engineer's life, depends on his efforts to apply the Creed and, even before that, on his knowledge of what this Creed, or any creed, means.

Dictionary definitions of creed include such phrases as "formula of belief," "summary of doctrine," "principle of action." It is possible that a complete definition of the word might go even further, for it seems universal among creeds that they contain, either explicitly or by implication, a dedication to those unselfish standards of service which ennoble man.

Creeds are found in practically every profession, every country, every century and every civilization from the beginning of recorded history. They fulfill, it would seem, a basic desire of man to stand up and be counted, not only for what he has been—in failure, success, hypocrisy and honesty—but also for what he would like to be—in a vision of Utopia that is at once a guide and a goal.

Creeds are expressions of ideals and, like many other abstractions, they are easier to read than they are to understand fully. Often they must be studied long and thoughtfully before their meanings can be completely grasped; not because they are vague, but because they are complex.

WHAT WE BELIEVE

often is formalized in a creed that we can use as a guide in our work and lives. Such is the Creed of the Safety Engineer.

Most creeds have gone through a slow process of development, and the present product usually is the result of the work of several generations of philosophers. Every paragraph, every sentence, every phrase becomes highly polished, concise, packed with significance. It might be said with some justification that our creeds are the most mature expressions of ideas man has achieved.

Undoubtedly the most well known creeds in our culture are those of the Christian religion. Probably the most widely used by churches today are the Nicene Creed and the Apostles' Creed, both of which have gone through a number of variations during the centuries since they first were formulated. In general, the form and content of the Nicene Creed dates from the year 325, the Apostles' Creed from about 400. But even before this, confessions of faith had been written which contained many of the ideas, and even some of the phrases now used.

Many engineering societies have adopted creeds, most of which are similar. In wording, these creeds do not have the antiquity of the religious creeds. But in ideas, the engineering creeds are as old as the concepts of truth, honor, duty and brotherly love. And it is these age old principles that members of the American Society of Safety Engineers affirm their belief in, and dedicate themselves to, with the Creed of the Safety Engineer.

by H. W. Heinrich

The Accident Cau

H. W. Heinrich, superintendent, Engineering and Loss Control Division, Travelers Insurance, is the author of four books, including "Industrial Accident Prevention," which reported the 88:10:2 ratio.

PRO

Physical Hazard May Call for First Attention

But Ratio Shows Manfailure as Prime Cause

Needing Corrective Action, Heinrich Maintains

MAN or machine as the prime factor in accident causation is a subject that provides fuel for much discussion and difference of opinion. The differing opinions simmer down basically to three in number. One concludes that man is chiefly at fault. One believes that machine is the guilty party and the third opinion is that both man and machine are responsible in practically all cases.

There is danger, real and tangible, in any one of these three points of view when held by any individual who himself or through his influence or authority, controls or directs the work of accident prevention and who, because of the misapplication of his belief, permits correctible accident causes of *any kind* to exist.

It is high time to "clear the deck" for action toward an agreement to which everyone surely will subscribe, namely:

"When a machine, tool, structure, procedure, process or anything else of a mechanical nature is involved in accident or injury, first consideration invariably should be given to the possibilities of correction that lie in guarding, relocating, rearranging, automation and other forms of engineering revision, regardless of whether the primary cause is man or machine."

This is but good sense. If a machine can be made foolproof, by all means let's make it so. A mechanical hazard is tangible and often subject to quick control. It ought to be corrected, if at all practicable, whether or not it causes an injury or accident.

The foregoing agreement is the stated creed of the writer, who also is responsible for reseach leading to the publication of the often quoted and misquoted ratio which shows that 88 per cent of all industrial accidental injuries are caused chiefly by unsafe acts of persons, 10 per cent by mechanical causes and 2 per cent by so-called Acts of God. The agreement and the ratio are not in the least inconsistent, although they may appear so to the casual reader. The first—the creed—refers to *primary consideration of corrective action.* The second—the ratio—refers to *primary causation.*

It is true that in general the primary cause should prompt the corrective action. That's why it must be found and recorded. But it certainly should not prohibit *first* action of an obviously common sense nature on a subcause. An excellent example is that of an eight year old who filched a box of six inch, salute-type cannon crackers from an unattended parked truck delivering supplies for an unauthorized fire works display. His father came upon the boy sitting on the porch at home, holding a cannon cracker and about to light the fuse with a match. Here is an accident and serious injury in the making. Clearly from primary cause analysis, everything points to unsafe acts and manfailure—the action of the youngster and the unattended truck. But when it comes to *first corrective action,* no one will disagree with the father who at once recognized the potential physical hazard and knocked both match and cannon cracker out of the boy's hands. Then he proceeded with his educational effort, and who would disagree with the long range value of recording the primary cause as *personal* or with the pressing need of a personal remedy to prevent future similar actions of the boy, the driver and the community enforcement officials!

In conformity with the creed is the accepted maxim, "Safety begins with a well guarded work place—with safely designed processes, procedures, structures, tools and equipment—with guarded equipment—with good housekeeping and adequate light, heat, ventilation and sanitation." This is basic thinking and because it is so, it justifies consideration always of opportunities in the correction of mechanical hazards. It does not justify failure to select prime causes of accidents when these are of a personal nature.

To be truly objective one should keep in mind that *prevention* of accidents and injuries is the aim of industry in the safe production of goods and services. It follows that knowledge of causation is essential as a guide to preventive action. It is clear also that knowledge of all correctible causes, both primary and secondary, both personal and mechanical, is necessary. Practicality and expediency then play a part in selecting the first corrective step in prevention. For example, if a workman in violation of repeated instructions deliberately and unnecessarily tampers with a well guarded machine and becomes injured—if in this case the addition of a more tamper-proof type of lock is practical—by all means install that lock.

In such a case, however, is it good procedure to overlook the fact that the workman deliberately acted in an

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by Roland P. Blake

Ratio — 88:10:2

Roland P. Blake, consultant, Bureau of Labor Standards, has written many articles and is editor and co-author of the book, "Industrial Safety," in which the accident cause ratio is discussed as a fallacy.

Ratio Concept Is Fallacy, Harmful to Safety Because Used to Rationalize Neglect Of Unsafe Mechanical Conditions, Blake Says

CON

IN MY opinion the very concept of a ratio between physical hazard and unsafe action in injury causation is both fallacious and harmful. The purpose of this discussion is to present the considerations that have brought me to this belief.

Note that I use the term "injury" rather than "accident." The primary purpose of accident prevention is, of course, to prevent injuries but unfortunately many people use the terms "injury" and "accident" synonymously. I wish to avoid contributing to that confusion. If we define "accident" as "any unplanned or uncontrolled occurrence that interrupts or interferes with the orderly progress of the activity in question," it becomes clear that when we use the term "injury" in this connection we mean an injury caused by the accident. The misuse of these terms undoubtedly resulted from superficial thinking in the early days of the safety movement followed by unthinking acceptance of this misuse by many ever since.

I consider the ratio concept another case of superficial thinking. Who started it I do not know but its wide unthinking acceptance has done much through the years to retard and inhibit the work of accident prevention, as I shall try to show.

The idea that injuries are caused by *either* physical hazard *or* unsafe acts is an appealing one because it is so simple. Just guard the hazard *or* get the fellow to work safely—make him safety conscious and—no more injuries. But it doesn't work out. "Of course not," say the acceptors of the either/or idea. "Some fellows are just naturally careless, or they are accident prone, or they deliberately disobey instructions," and so on. We've all heard those alibis and others like them. There is a measure of truth in each of them. Perhaps the term alibi is too strong because probably they are rarely if ever used consciously as alibis; they are just further evidence of superficial thinking.

We are all guilty of superficial thinking at times but let's see if we can't get down to fundamentals on this issue and find out where it will lead us. We'll start with the factor of physical hazard. Is an injury possible without some degree of hazard? Chew on that one a while. You'll be forced to say no. Next ask yourself if a hazard can injure unless "it makes contact," as our military friends would say. That brings in the unsafe act as any action that causes or allows a hazard to make contact. But sometimes it's lack of action that permits contact, so we broaden our term to "faulty behavior" to include the whole bag of tricks—unsafe action, unsafe inaction, inadequate action, wrong action, etc.

If you accept this line of reasoning you must admit that the ratio concept is inapplicable—fallacious—in expressing the relationship between physical hazard and faulty behavior, or as H. W. Heinrich puts it, "man failure." To any reader who still cherishes the ratio idea I would say, "Use a 100 to 100 ratio if you must have a ratio, for that and only that is valid."

Incidentally, it is surprising to me that so many safety engineers have accepted the ratio concept. Of course, ratios are a much used tool in engineering, particularly in expressing specific relationships having to do with the materials and forces the engineer works with. But engineers are trained to think in terms of fundamentals and also to demand accuracy. So I am still surprised.

But perhaps I'm expecting too much even for engineers. Let's run over the history of this ratio thing to find out how it came about. So far as I know, Heinrich's study reported on in his book, "Industrial Accident Prevention," was the first attempt to establish a definite ratio. A careful reading of his language shows clearly that his purpose was to find out in what proportion of injuries an unsafe *mechanical* condition was the more important causative factor and in what proportion an unsafe *act* was the major factor. As probably every reader knows, this study brought the ratio 88:10:2—88 human failure, 10 mechanical hazard and 2 unpreventable.

There is nothing in Heinrich's language to indicate that he regarded his ratio as more than an approximation. Furthermore, it was gained partly from injury reports made for the purpose of determining the compensation due and partly "from the records of plant owners." But except where such reports are based on thorough investigation by competent personnel, the information as to cause is limited and frequently unreliable. In other words, the analysts going over the 75,000 accident reports covered by this study had to do a lot of guessing. But my hat is off to Bill Heinrich for it was a tremendous undertaking. It must have been a labor

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unsafe manner, that with his attitude unchanged he will in all probability do similar things again and that through competent supervision both his attitude and practice may be improved? Yet when accident cause-analysis charges such accidents to machine and not to man, or even when both causes are given equal weight, attention is directed away from instead of toward the place of greatest long range opportunity.

The great majority of electrocutions of linemen in public utility operations occur almost wholly because of failure to wear rubber gloves, to use insulating protective equipment such as rubber pigs and blankets, to follow prescribed safe procedure in disconnecting sources of energy, in grounding and in maintaining safe clearances. In practically all of these cases, a mechanical exposure in some degree existed. For example, the very fact that linemen must work at times in proximity to live wires carrying high tension current indicates the existence of a mechanical hazard.

Is Hazard Prime Cause?

This hazard, as in the prior example, should receive first consideration. But should it be recorded as the prime cause? Practicality and expediency direct attention to personal unsafe practice as a primary cause when a lineman who fails to wear rubber gloves is electrocuted.

There is general agreement also that traffic accidents are caused primarily by the unsafe action of the driver or pedestrian. In this connection it is of interest to note that the National Safety Council's "Accident Facts," 1955, shows that about 94 per cent of vehicles involved in fatal accidents for which condition was stated *had no unsafe condition.*

To the writer's best knowledge only one comprehensive attempt has ever been made to assign major responsibility—in consideration of time sequence, practicality, expedience, and best effect on the prevention of similar accidents—to but one of these two causes in cases where both exist. The results of that study were first published in 1926 and appear in "Industrial Accident Prevention" under the caption, "Man vs. Machine," as the ratio 88:10:2, the 88 per cent applying to accidents caused primarily by man. In 75 per cent of the 75,000 cases thus analyzed, there was no need to choose between the personal and mechanical causes as *there was but one* cause, as when a hand trucker walking backwards while pulling his truck along a well marked aisleway, under excellent housekeeping conditions, bumped into a properly located concrete post.

In the 25 per cent residue, both personal and mechanical hazards existed, *but not always to the same degree.* Judgment was exercised. In balanced and doubtful cases, preference was given to the machine cause. After careful consideration, only one cause was assigned for recording and coding purposes. The basis of selection has already been described. In the majority of instances it pointed definitely to manfailure.

Contrasted with the method of analysis described in the foregoing is that which results in the ratio of 94.9 per cent unsafe personal acts and 94.5 per cent unsafe mechanical conditions. Admittedly, in arriving at this almost exactly balanced ratio, both causes when present were recorded for each accident and no attempt was made to select the cause of most importance in prevention.

The *method* of approach therefore accounts chiefly for differences of opinion and not the belief based on cause-analysis that one ratio or another is in error.

Some Call Ratio Harmful

Some capable and conscientious safety engineers have said that "the publication of a ratio showing manfailure to be the primary cause of accidents is harmful because it encourages persons who are responsible for the correction of unsafe mechanical conditions to evade their responsibilities on the basis that such conditions have an insignificant place in accident occurrence."

Proof that this belief has widespread or disturbing application is difficult if not impossible to obtain. This writer doubts its validity. He is of the opinion that one who evades responsibility on such a basis would readily find some other available excuse. In the face of legal requirements the excuse would have no weight whatever. Where no legal requirements exist, he would need no such excuse inasmuch as those who might suggest correction of mechanical hazards would have no authority.

Furthermore, the 88:10:2 ratio does not negate the field of mechanical guarding. Ten per cent still represents a sizable number of accidents caused by machine, especially when these are *primarily* or *wholly* so caused.

Members of the safety profession and industrialists in general can be assumed *to want the facts,* whatever they indicate. Granted that it may be simpler to guard a machine than to control the performance of an employe, yet should we imitate the proverbial ostrich and ignore the facts by failing to select primary causes?

The profession will welcome further research with regard to man versus machine in accident causation. When it has been accomplished its findings should be accompanied by a statement of the method used; that is, by mention of the basis of selection of responsibility. This is necessary to prevent misunderstanding.

Pending the publication of such further data the 88:10:2 ratio stands alone and on its own feet as an attempt to determine the major direct cause of accidents. It remains undisputed as yet by other than honest personal opinion. It quite properly features the personal unsafe act as the major direct cause of accidents.

Manfailure Emphasis Pays Off

As a direct result of emphasis on manfailure, the records are replete with cases of low accident frequency and severity rates achieved through management interest and participation, supervisory control of employe performance, publicity, education and organization.

Thanks to the original and still-continuing emphasis placed on machine guarding and other physical or mechanical safety efforts, marked improvement has been made in accident frequency from mechanical sources. Those who feature such methods above all else and who at the same time fear the emphasis being placed on manfailure, should find a source of gratification in a ratio showing so clearly that a reduction from an indefinite yet undoubtedly high figure to but 10 per cent of all

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of love indeed. The man hours required to go over 75,000 injury reports one by one and decide in each case which was the major causative factor must have run into big figures.

A study conducted by the National Safety Council found unsafe mechanical conditions in 87 per cent of the cases studied and unsafe acts in 78 per cent. The Department of Labor and Industry of Pennsylvania classifies the injuries reported under their Workmen's Compensation law as to mechanical cause and unsafe act. Year after year they show results similar to those of the Council study. I view the findings of these studies as lending strong support to my viewpoint. My own experience in investigating accidents reported for insurance purposes gives even stronger evidence. Thorough investigations made promptly enough to get the facts rarely fail to bring both physical hazards and faulty behavior to light. The weight of evidence supports the the common sense conclusion that injuries are the product of physical hazard *and* faulty behavior, rarely if ever either one to the exclusion of the other.

Early Safety Chiefly Guarding

Let's go back into history a little further — before Heinrich brought out his book. The first 15 years or so of the organized safety movement were devoted primarily to the elimination of physical hazards, chiefly guarding machinery. But the cost was heavy partly because little or no thought had been given to safety in laying out and equipping any but the newest plants and partly because most machines were still run from line shafting. The average large plant had thousands of feet of shafting, miles of belting and gears of all sizes and types, all busily carrying power from the prime mover on to the individual machines. Projecting set screws were everywhere too, until the counter-sunk type was developed and shown (after a long drawn out battle) to hold as well as the projecting type. Even as late as 1930 set screw hunting was a favorite sport for state and insurance inspectors.

The cost of guarding in such a plant ran high even in those days when the dollar would purchase perhaps three times what it will today. So naturally management squirmed and when, through the pioneer work of U. S. Steel and a few other safety leaders, the great value of safety committees in developing safe practice was demonstrated, they looked like the answer. Safety committees proliferated and the emphasis was increasingly placed on "arousing and maintaining employe interest." The terms "safety mindedness" and "safety consciousness" became cherished items in the vocabulary of just about everybody concerned with promoting the cause of safety.

Why Spend Money on Guarding?

Cost minded management naturally reasoned that if injuries could be prevented by developing safety consciousness, why spend substantial chunks of money to guard any but the more serious hazards?

Undoubtedly the ratio idea was born more or less simultaneously in many men's minds during this period. I know I "met up with it" in the early nineteen twenties. And now on looking back to that period I must confess that I'm surprised at myself, for I accepted the ratio concept for a while and even carried on a little research of my own to determine what the ratio actually was. Even after I perceived the fallacy in it, I didn't try much to combat it. It's awfully hard to swim against the tide, you know.

Before Heinrich announced the findings of his study the ratio 15 to 85 was probably quoted most often. After that the odds sank to 10 to 90, a change that was most comforting to those who consciously or subconsciously were willing—perhaps even anxious—to prevent injuries if it wouldn't cost much.

Another factor has undoubtedly clouded this issue; namely, management concern and resentment over the ever increasing and more detailed state guarding requirements. In the beginning the state labor law administrative agencies played a very important part in cutting down the flow of serious injuries and deaths by developing safety regulations and enforcing them through factory inspection. Progress in safeguarding would undoubtedly have been much slower without state inspection.

As compliance with guarding regulations was increasingly secured, the injury totals from the hazards covered progressively declined. Finally the year-by-year reductions became so small as to be undiscernible. Instead, however, of broadening the safety inspection service in the light of the progress made in the field of accident prevention by private industry, the state agencies practically without exception merely continued their routine inspections and increasingly included unimportant details. They justified their budgetary requests—and mostly still do—chiefly or wholly by the number of inspections made and number of orders written without any reference to their value in preventing injuries.

Factory Safety Laws Punitive

The genesis of this situation is to be found in the factory safety laws themselves. They are primarily punitive. They were passed in the belief that employers as a class have to be forced to provide essential safeguards and that such safeguarding is the all important thing—the *all* of safety. So with very few exceptions the leaders of the state inspection services have taken no part in the organized safety movement and have little real knowledge of accident prevention.

You may wonder why I have written the foregoing. It is necessary to show some of the harm the ratio concept has wrought. The great majority of the annual occupational injury totals come from establishments too small to justify competent full-time safety personnel. Many of them are doing a good safety job but the majority are not and have high injury rates without knowing it. Their seeming indifference to safety is due to ignorance of what top rate safety performance is and why it would benefit them to achieve it.

The 10 to 90 or some similar ratio is very appealing to such managements because they naturally reason that if nearly all injuries are due to unsafe acts, they have little responsibility for employe safety. They charge the injuries to carelessness. And since a behavior fault can

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accidents chargeable to the machine, has been achieved.

The following conclusions seem to be appropriate and defensible:

Accident Cause Analysis

1. The determination of facts as to the cause of each individual accident should precede and guide action concerning the prevention of similar accidents.
2. When determining facts as to accident cause, consideration should be given to both personal and mechanical causes *and* the effort should be made to decide which of the two is chiefly at fault.
3. If means exist to record both kinds of causes, then in cases where both exist, the one chiefly at fault should be recorded as number 1 and the second one shown in second place. This should be done regardless of the practicality of eliminating the selected cause (see items 6 and 7).
4. Causes should be determined *specifically* as items within the two general groups of personal and mechanical causes.
5. Mass cause data are extremely valuable in directing attention to the probability of accident occurrence from specific unsafe acts or conditions but neither such data nor any preconceived opinions should deter the investigator from the effort to find and record *all the facts*, nor from selecting that which in his best judgment is chiefly at fault.

Corrective Action Indicated

6. Inasmuch as the approved basic concept of industrial safety envisions a mechanically safe environment, first consideration in deciding on corrective action should be given to machine guarding and other forms of engineering revision, whether or not the chief fault lies in the personal unsafe act group. Concurrently action should also be taken to correct the personal fault when both kinds of causes exist.
7. When, as in the majority of cases, the personal unsafe act predominates and the unsafe condition is either absent or of a minor nature, consideration of a mechanical remedy, while still to be given as above suggested, should lead quickly and almost automatically to the selection and application of personal corrective action.

Statistical data together with the graphs and ratios derived from statistics are often claimed to serve entirely opposite viewpoints. True or false, no effort should be neglected to so present mass data as to eliminate probable opportunities for misunderstanding.

One such opportunity is indicated by this discussion; namely, the inclusion of accompanying and explanatory statements. These should cover the method or basis of selecting the data for the factors involved, definitions of headings and factors, and references to known data on the same subject.

It is the writer's hope that the publication of this material may be of some assistance in promoting a keener interest in the subject of man versus machine with regard to accident causation and perhaps also in encouraging effective prevention efforts based on established facts.

always—or almost always—be readily found when some workman gets hurt, they regard it as proof of the validity of the ratio.

I've had many contacts with this frame of mind because through the 21 years of my service with the Bureau of Labor Standards I have made it a practice to call on small plant managements at every opportunity. In many cases the plant management has invited me. The manager's viewpoint in the following case is typical.

About three years ago I was one of the morning speakers at a community safety conference. My subject was "The Appraisal of Plant Safety Performance." At the close of my talk the manager of a plant in the area introduced himself to me and after some discussion asked me to have lunch with him and look his plant over. I accepted. It was a typical foundry and machine shop making chiefly sub assemblies and parts.

Records Show High Injury Rate

His injury rate for the previous year, calculated from his reports to his insurer, was about 47. There was one amputation (a finger) and one serious burn. The rest were run-of-mine. The cost to the insurance company appeared to be well within the premium so the insurance inspector hadn't asked for much.

The manager—I'll call him Mr. Doe—blamed the injuries on carelessness, citing a number of cases called to his attention by his foremen. He particularly wanted me to tell him how to deal with carelessness. I told him I'd like to look over the plant and talk to the foremen first, a suggestion he welcomed. He asked me to point out anything that was unsafe. There were plenty of things but as I pointed them out his enthusiasm waned visibly. Finally he came out with, "Look here, Blake, I need help on this (blank) carelessness. Yet all you talk about are ways to spend money. Everybody knows that unsafe acts cause 90 per cent of all accidents. I'd be a sucker to spend a lot of money on the 10 per cent first. I'll go after the 90 per cent. When I get that licked I'll think about the 10 per cent."

That fellow rumpled my pride so I really went to work on him and finally made a sale. But it was tough going. I stayed over the next day and followed up by mail and a couple of calls back during the next few months.

Changes Approach, Improves

He is now doing a top rate safety job and has the carelessness thing pretty well licked. Incidentally, he joined the National Safety Council, entered a contest and is well on the way to an award.

I'm sure Mr. Doe would bear witness to the fallacy of the ratio concept, for it led him astray. His approach now is the same as that of every management that has brought its injury rate down close to the vanishing point. Stated briefly this is—"Maintain a thorough and painstaking joint program of hazard elimination *and* of safe and adequate behavior development." Never let up.

Now, dear reader, if you don't see both the fallacy in that ratio concept and the harm in it, my words have been wasted. If you agree with me, let's bury it deep.

Cutting and Welding FIRES

A Continuing Challenge

by L. G. Matthews
Secretary, Oxy-Acetylene Committee, International Acetylene Association

L. G. Matthews is assistant manager, Safety Codes Department, Union Carbide and Carbon Corporation. He is a graduate of Purdue in chemical engineering.

THERE is no question but that some safety engineers believe we have done all we can to reduce cutting and welding fires—that the subject has been exhausted by literature and lecture. To be sure, the subject is hardly new. Twenty years ago there were articles on the "how to" of preventing these fires, and their message still holds today.

But the fact remains that while cutting and welding are sometimes overemphasized as causes of fire losses, there are far more such fires than there should be.

What are the facts in the case? Admittedly statistics on the subject are not exhaustive. Today's reporting will not permit interpretation to tenths of a per cent. However, those who have for many years been concerned about welding and cutting fires are in general agreement with the figures mentioned in the following paragraphs.

In brief, about nine out of ten fires traceable to cutting and welding occur when the work is done in a temporary location using portable equipment. Welding shops and other "permanent," production-like setups are usually constructed and safeguarded so that fire possibilities are very much minimized. Almost the same ratio—eight or nine out of ten—of the fires are a result of cutting as compared to welding.

Some surveys point up the part played by portable equipment in even more emphatic fashion. Several years ago Western Underwriters Association examined 92 losses of over $10,000 each that started from welding or cutting. Every one of the 92 was attributable to mobile equipment. It is interesting to note from the same study that 20 of the 92 losses were laid to "outside contractors," a proportion perhaps somewhat smaller than usually conjectured. The Factory Mutual Record for March, 1954, said, "Nearly one-third of 311 cutting and welding fires reported by Factory Mutual insured properties in a recent typical year were caused by contractors."

The Ounce of Prevention

The steps to be taken to prevent cutting and welding fires are no secret. Information of this kind has long been widely published in detail by a variety of sources—the welding industry and equipment suppliers and their associations, insurance groups, the National Fire Protection Association and others. No re-recital of the "do's and dont's" will be given here. A list of some of the outstanding subject matter of this type appears at the end of this article.

The basic preventive measures are simple. They are not hard to understand. They all harken back to the fact that in welding and cutting operations two sides of the fire triangle are always present; namely, a source of ignition and air to support combustion. The other (and therefore controllable) element is the combustible material.

Boiled down, the essentials of cutting and welding fire prevention are:

1. Move the work to a safe location.
2. Move combustible materials a safe distance away.
3. If (1) or (2) is not possible, then by means of suitable fire-resistant guards (sheet metal, asbestos, etc.) protect the exposed combustibles and have someone standing by to extinguish any fire promptly.

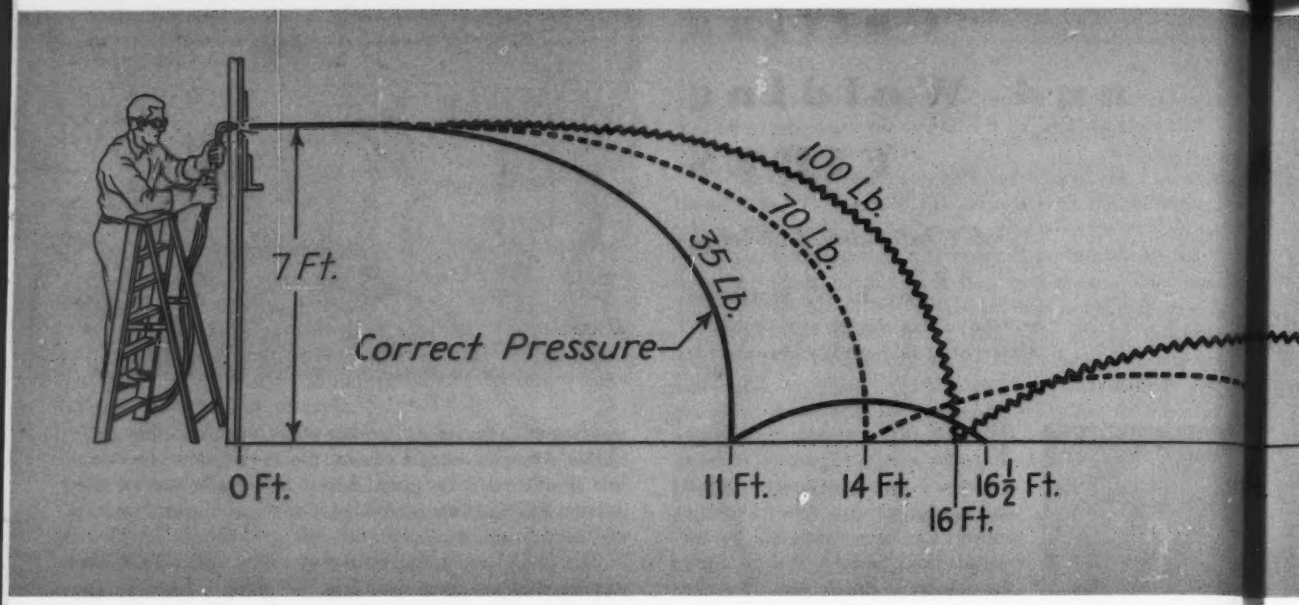
If one of these three simple conditions cannot be satisfied—and preferably in the order listed—it may well be that welding or cutting should not be done in the area in question.

To the above should be added two more items of major importance. First, it is good policy to make some competent individual responsible for the use of portable equipment. Second, the welding or cutting operator should always observe the equipment manufacturer's instructions for setting up and manipulating the particular apparatus in use. Procedures for correct handling of one make of cutting or welding torch will not necessarily apply to any or all others.

Still Something Missing

Where then does our problem arise? Why are we still plagued by cutting and welding fires, big or little? It will do us no good to debate such questions as the exact source of fires from these operations — whether from hot metal, hot slag or sparks. The practical fact is that they are all present and are all capable of starting a fire.

Do we lack controls? In larger industrial establishments systems of "welding and cutting permits" or "hazardous work permits" are often used. They help reduce the chance of serious fires being started but are not infallible. They require prior inspection of the work location by one or more supervisors or persons in author-



Protect floor or wall openings to shield adjacent areas from sparks.

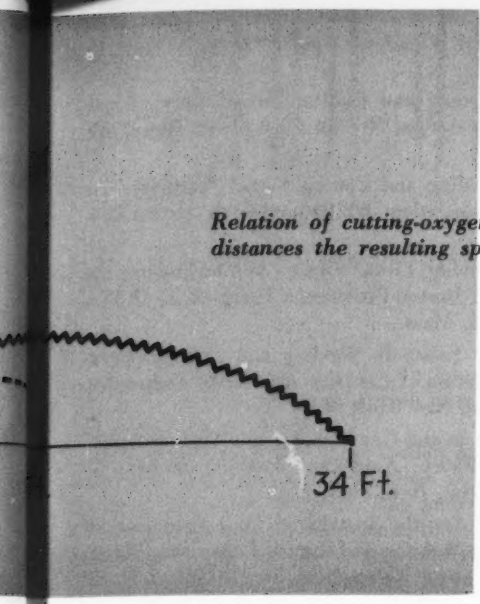
CUTTING AND WELDING FIRES *Continued*

ity and sometimes a re-inspection after the work is completed. Smaller plants or those engaged in construction and demolition work may not think these permits practical. In any case they are still dependent on the carefulness, judgment and diligence of those who authorize the work.

At its annual meeting in 1954 the International Acetylene Association held a panel session on prevention of welding and cutting fires. At that session the safety director of one of the major suppliers of welding and cutting equipment suggested that it may be oversimplification to say that fires occur just because combustibles are too close to the welding or cutting operation or inadequately protected from it. This is an interesting and provocative thought.

The distance or degree of protection that will adequately safeguard materials from a nearby cutting operation may depend on the specific combustible material, its ease of ignition and rate of burning, the method of piling or storage, the quantity stored, sprinkler protection, pro-

Before cutting or welding in new location, operator should check with area foreman or supervisor.



Relation of cutting-oxygen pressures to distances the resulting sparks will fly.

vision of fire watchers and other related factors. With an adequate understanding and appreciation of the risks involved, a practical decision on amount of separation or type of protection can be made.

Another interesting clue to the problem appears in the following table taken from a mailing insert prepared some time ago by South-Eastern Underwriters Association:

CAUSES OF FIRE LOSSES FROM CUTTING AND WELDING

Insufficient preparation	49%
Floor and wall openings admitting sparks to adjacent areas	18%
Impaired protection	18%
Defective welding equipment	5%
Miscellaneous conditions	10%
	100%

"Insufficient preparation" is a most apt description. It says neatly and simply what it is that turns the area of a temporary cutting or welding job into the scene of a fire. Actually, what is "floor and wall openings admitting sparks to adjacent areas" but more "insufficient preparation"? Closing or covering those openings would probably have made the preparation sufficient. So on this basis something more than half of the losses go back to failure to evaluate the risks properly or to do enough about them before the job was started. Even "impaired protection" and perhaps to some degree "defective welding equipment" are "insufficient preparation." It is interesting to see that this group (South-Eastern Underwriters) finds only five per cent of the fires due to defective welding equipment.

From this it seems rather clear that the cutting or welding operator is more alert to the potential hazards in leaking connections, worn hoses and damaged or plugged torch tips than he is to the potential hazards of the surroundings in which he works.

The Heart of the Problem

What's behind insufficient preparation? Why aren't sufficient preparations made? To our knowledge no one has ever attempted to compile statistics or data on this point. However, from experience it would seem almost certain that some of the reasons would be: eagerness to make a quick repair to prevent a production loss; errors in judgment in assessing the risks involved; the "it-can't-happen-here" attitude; and just plain carelessness.

Without benefit of statistics, data or tables, all these things and others like them can be lumped into one—insufficient training. This is the crux of our problem. Better training, better education of the man with the torch in his hand, and in some cases of his foreman or supervisors, is the indicated positive attack to reduce cutting and welding fires. A properly informed and instructed person will not deliberately light a torch or permit one to be lighted if there is a chance of a fire. Remember too that the cutting or welding operator at

Cutting operations are responsible for majority of cutting and welding fires.

Failure to move or protect combustibles and wet down wood floor before cutting may mean fire.

CUTTING AND WELDING FIRES *Continued*

work does not have full vision. His goggles limit his sight to the point of his work, and exposure to heat from the torch dulls his possible alertness to any other fire in the immediate vicinity.

To get the operator to prevent a fire, he must be educated to anticipate it, educated to evaluate the surroundings intelligently and educated to make these things as much a regular part of his activity as turning on the torch valves before lighting up.

Professor John J. Ahern, director of the Department of Fire Protection and Safety Engineering, Illinois Institute of Technology, had this to say at the time of the International Acetylene Association meeting in 1954:

Must Reach 'Man on End of Torch'

"The education problem is probably the toughest one we have to face. Getting to the employe—the man who is using the torch—is the number one problem. There is no disregarding the fact that the welding equipment representatives and the insurance underwriters cannot get to the employes directly. They must get to them through management, through training programs in industry. And in order to accomplish that, industry must be willing to devote the time to get that message across. Unfortunately we are not reaching the man on the end of the torch."

This is no small order. To meet the continuing challenge to educate against cutting and welding fires will require the combined efforts of every safety engineer, safety supervisor and instructor—especially those in a position to work closely and regularly with the "man on the end of the torch." The teaching medium will probably depend on individual situations or choices, but none of the techniques such as safety meetings, literature distribution, film strips, new employe job indoctrination—and even oral or written examination—should be overlooked.

Some Publications Dealing with Prevention Of Cutting and Welding Fires

"Preventing Welding and Cutting Fires," International Acetylene Association, 30 East 42nd Street, New York 17, N. Y.

"Preventing Welding and Cutting Fires," National Fire Protection Association, 60 Batterymarch Street, Boston 10, Mass.

"Cutting and Welding Fires," Factory Mutual Engineering Division, 1151 Boston-Providence Turnpike, P. O. Box 510, Norwood, Mass.

"Your Guide to Safety in Welding and Cutting Operations," Association of Casualty and Surety Companies, 60 John Street, New York 38, N. Y.

"Safety in Electric and Gas Welding and Cutting Operations," ASA-Z49.1, American Welding Society, 33 West 39th Street, New York, N. Y.

"Safe Practices for the Installation and Operation of Oxy-Acetylene Welding and Cutting Equipment," International Acetylene Association, 30 East 42nd Street, New York 17, N. Y.

"Installation and Operation of Gas Systems for Welding and Cutting," Standard 51 of National Fire Protection Association, 60 Batterymarch Street, Boston 10, Mass.

"Manual of Accident Prevention in Construction," Associated General Contractors of America, Munsey Bldg., Washington 4, D. C.

"Safe Practices for Welding and Cutting Containers that Have Held Combustibles," American Welding Society, 33 West 39th Street, New York 18, N. Y.

"Welding and Cutting," Chapter 29 of "Accident Prevention Manual for Industrial Operations," National Safety Council, 425 North Michigan Avenue, Chicago 11, Ill.

Literature published by suppliers of welding and cutting equipment and gases.

Sparks are kept close in to work through use of suitable fire-resistant guards.

100,000 GALLONS A MINUTE

by William G. Ball Jr.

ONE hundred thousand gallons a minute is a lot of gasoline, but it takes this much to move the people and products of this great nation.

Since gasoline is so widely used, safety engineers should regard the safe handling of gasoline as a logical part of any overall safety program. The precepts of gasoline safety are fundamentally the same as those of many other flammable liquids and gases; only the varying characteristics of volatility, combustible limits and toxicity require individual treatment.

This article will be limited to fire and explosion hazards and fire fighting. In discussing these subjects, it is important to describe first the conditions under which a substance will ignite. With but few exceptions, such as sodium's reaction with water, there are three essential conditions necessary for combustion—oxygen (air), heat (ignition temperature), fuel (vapor)—and they must exist at the same time and place.

When an open flame is passed over pieces of wood and coal, and over beakers of kerosene and gasoline, only the gasoline ignites. The characteristic that sets all highly volatile and flammable liquids apart from other fuels is their ability to vaporize at ordinary temperatures—in fact, as low as 45 degrees below zero for gasoline. Wood, coal, and kerosene must first be heated before sufficient vapors will be liberated.

Combustible Mixtures

In the case of gasoline, however, the vapors must be mixed with air in the proper proportion. With more than six per cent of gasoline vapor in air by volume, the mixture is too rich to burn. With less than one per cent, the mixture is too lean. Even in the presence of a very high ignition temperature, gasoline vapors will not ignite when these limits are exceeded by any significant amount.

A gallon of liquid gasoline will produce about 21 cubic feet of gasoline vapor. When mixed with air in the proportion of one per cent by volume, an explosive mixture can result. In other words, only one gallon of gasoline can create an explosive mixture within a room twenty feet long, ten feet high, and ten feet wide. That is why gasoline should never be used for cleaning floors, textiles, or tools. Similarly, a gallon of gasoline evaporated into the air within a 15,000-gallon tank would make the apparently empty tank a deadly explosion hazard for anyone who attempted to weld the tank or bring any other source of ignition within it.

Gasoline vapors are two to four times as heavy as air. They will creep long distances and collect in low places. If they encounter a source of ignition the vapors will ignite and flash back to their source, causing a fire there.

William G. Ball Jr., assistant to the public relations director, Ethyl Corp. An MIT graduate, he has written a gasoline text and many articles on fuel and engine subjects.

Sources of Ignition

The unsuspected sources of ignition are the most dangerous. In addition to the obvious examples such as a hot stove or the coils of an electric heater, there have been gasoline fires ignited by electric motors, electric switches and electric bells. Almost invariably, sparking occurs in the operation of these devices and unless they are designed to be vapor proof or explosion proof they can cause a fire whenever a combustible mixture is present. A broken electric light bulb can be a source of ignition for gasoline vapors (Figure 1). Once the glass is broken, the filament is exposed to oxygen and glows at a tremendous temperature for a short time before it is either melted or burned in two. And water can crack a hot light bulb.

As a source of ignition, static electricity is less obvious than switches, motors and light bulbs, but it is just as dangerous. Static electricity can be generated in the most amazing and unexpected ways. At one time it was thought that static electricity was generated by friction. Now it is known that friction in itself does not generate static electricity. Instead, it is the separation of particles—solid, liquid or gas—that creates the electrical charges.

Figure 2 shows what static can do. Merely by separating a metal disc from a piece of plastic, sufficient static electricity was generated to ignite gasoline vapors in the model tank. The resulting explosion blew the paper roof from the tank.

Wherever flammable liquids are being handled, safety engineers have to consider the possibilities of static electricity. The movement of any liquid, steam, and many gases through pipes or hoses generates static. Charges are also created when a liquid, discharged from a nozzle or pipe, breaks into droplets. Even pouring gasoline from one container to another builds up static electricity. In any continuous operation where there is movement such as in motor vehicles, tires, paper manufacturing, textile processing and in the movement of powdered materials, provision for the control of humidity or the grounding of static charges must be made if volatile combus-

Fig. 1—Water can break lighted bulb, cause fire in combustible atmosphere.

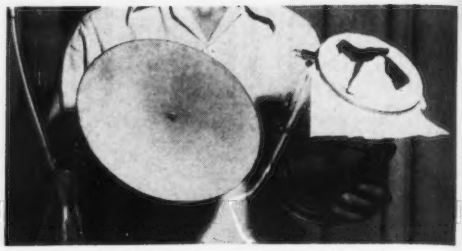


Fig. 2—Static electricity, generated on metal plate, caused gasoline vapor in tank to explode.

tibles are present in even the slightest quantity.

Even petroleum products with a high flash point can be hazardous if misused. The mere fact that a beaker of kerosene does not ignite in the presence of an open flame does not mean that kerosene is entirely safe in uses where it will be sprayed. Many paint solvents, insecticides and aerosols have characteristics similar to kerosene or gasoline. Safety precautions must be established by a qualified safety engineer for every process where liquids and solids are sprayed. And kerosene should never be thrown on a smoldering fire or used to kindle a fire in a stove. After heating the resulting vapors can cause a violent explosion.

Fire Fighting

The general principles of extinguishing flammable liquid fires should be included in any safety program. Containment should be the first thought. Once contained, fires of combustible liquids can be extinguished easily if employes have been taught to analyze the fire and to decide quickly on the best method of extinguishing it. Here again, the principles of combustion become the principles of fire fighting.

One progressive company, engaged in the manufacture of flammable liquids, taught its operating employes to analyze a wide variety of fictitious but highly probable fires. For these employes it became second nature to seek the best fire fighting methods because they had been drilled on the basic principles—"cut off the fuel," "cut off the air" or "lower the temperature of the burning substance below its ignition point." This type of training paid off when a high pressure pipeline ruptured. The flammable liquid quickly ignited from contact with a nearby electric motor. While many of the employes nearby sought to fight the fire with extinguishers, one alert employe merely closed the valve on the line. With the source of fuel cut off, the fire was soon extinguished. Figure 3 illustrates this principle.

In another instance fire broke out at the bottom of a storage tank where leakage was occurring. In this case, the product was such that it could be displaced by water, so a foreman ordered water pumped into the storage tank. This displaced the flammable material from the leak until the tank could be pumped out and repaired.

Whenever leaking gasoline or similar materials can be contained by open tanks, or by temporary dikes, oxygen can be kept away by blanketing the surface with foam or, in case of small containers, by improvising a cover for them.

Although flowing water normally spreads an oil fire, water is receiving increased attention when applied in the form of fog or spray. The tiny droplets of water tend to cool the fuel vapor below its ignition temperature and the steam (water vapor) produced by the fire's heat has a smothering effect as well. Often, fog nozzle protection permits employes to approach a fire near enough to apply other fire fighting chemicals and procedures.

A Rule for Safety

In studying industrial operations, safety engineers can follow this simple rule: If it is impossible to eliminate the sources of combustible vapors, then the sources of ignition temperature must be eliminated. Similarly, if the sources of ignition temperature cannot be eliminated, vapors must be prevented from reaching them.

Gasoline can be used or stored with complete safety so long as it is handled correctly and used only for the purpose for which it was manufactured—as a motor fuel.

Fig. 3—With the fuel supply cut off, a fire at a tank vent or leak will be extinguished.

Integrating THE HUMAN EQUATION INTO ELECTRICAL TESTING

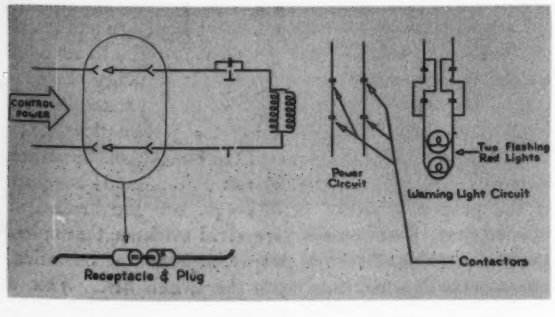
by C. R. DeReamer and H. E. Vann

IT IS often stated that a high percentage of industrial accidents, including electrical testing accidents, are due to unsafe acts. Reams of data and reports are available which classify accidents as having resulted from poor techniques, lack of judgment, recklessness and even downright stupidity. Thus, the conclusion is made that all that needs to be done is to eliminate these unsafe acts and accidents will stop.

One of the major objectives of this paper is to demonstrate that these so-called unsafe acts in the electrical testing field may not be the fault of the electrical tester or the test engineer. Evidence exists which indicates that many so-called operator errors have been touched off by faulty design of the test equipment, poor working conditions, operating practices that expose the tester to hazards, or lack of standardization and identification which so confuses the operator that he is psychologically trapped into making mistakes.

Any discussion of electrical safety should start from the basic premise that engineering skill for controlling electricity and an exact knowledge of the effects of electricity on the human body are available. Therefore, steps can be taken to design electrical test setups that will isolate the tester from live electrical circuits or so limit the current values that the contact will not be harmful. Experience has proven that it is not enough to design the test setup just to satisfy the functional requirements of the operation. It is also necessary that the engineer include the human equation in his set of formulae, standards and specifications. If this approach is carried out in practice, fewer accidents should result, training time will be reduced, and costly changes in the test setup after it has been put in use will be eliminated. In the design of electrical test equipment and the development of test methods, certain considerations must be taken into account so there will be an adequate integration of the human factors into the functional requirements of the test; namely, standardization, identification, proper operating sequence, failure of equipment, circumventing safety devices and the tester's fellow employes.

Fig. 1—Typical interlock circuit shows plug and receptacle and component parts of circuit.



C. Russell DeReamer, consultant, safety services, General Electric, serves on three ASA sectional committees and NSC's Industrial Conference Board, has authored a number of articles on safety.

Harold E. Vann, member of AIEE, is former test engineer and safety engineer for General Electric. He recently was assigned to marine nuclear engineering in the Atomic Power Equipment Department of GE.

STANDARDIZATION: Recognizing the necessity of providing maximum safety in electrical testing, the General Electric Company has established standards in its "Testing Safety Rule Book," maintained over a 16-year period to aid the test designer and methods man in integrating the human and functional requirements into the design of electrical test setups and to assist the first level supervisor in establishing practical safety requirements for electrical testing operations.

The standards are based on the basic principle that safety standards must implement and not impede production. The rules are hinged around two broad objectives:

1. To isolate electrical hazards with interlocked enclosures that will automatically interrupt power when a hazard is present.

2. To design characteristics into the test equipment and safety devices that will automatically remove power and eliminate the hazard in case of an equipment failure or malfunction. These are called "fail safe" characteristics.

The influence of these two broad objectives can best be illustrated by reviewing some basic standards and the sequence in which they may be developed.

The first and most logical step in electrical testing safety is to build an enclosure around the equipment being tested that will isolate the hazard inside the enclosure so contact with a "live" electrical part can not be made from outside the enclosure. This would be sufficient if the operator always followed the proper procedure and removed power before entering the enclosure, but experience indicates a need for additional consideration.

The next step is wiring all primary power to the enclosure through a visible disconnecting device. The discon-

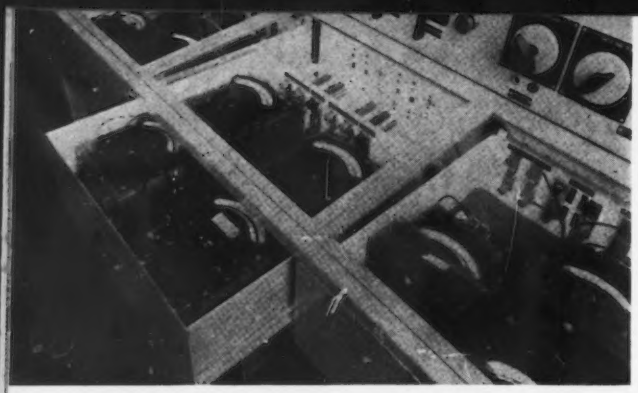


Fig. 2—Test table with interlocked meter and instrument enclosures. Circuit is automatically broken when meter terminals are exposed.

ELECTRICAL TESTING *Continued*

necting device must be arranged so that it is apparent from visual observation if the circuit is open or closed.

As a check on the disconnecting device, a single red light can be added to the enclosure to indicate when power is on and a hazard exists inside the enclosure. However, the operator's awareness soon becomes dulled to a single red light. To correct this condition a flashing red light can be substituted. But what happens if the single light burns out? Obviously the operator might be trapped into thinking power was off. By modifying the setup to include two flashing red lights in parallel this condition can be eliminated. The lights can be so installed that any malfunction of equipment or sticking of a contactor or breaker will keep the lights flashing and denote the presence of a hazard. However, unless a carefully supervised maintenance procedure for replacing burned out lights is established, and followed, the two lights will be little better than a single light.

The use of a test enclosure and flashing red lights to indicate a hazard inside the enclosure still is not sufficient because workers are sometimes likely to forget to follow normal routine. Under such circumstances they might enter the enclosure without first removing power. The next step is to add an electrical interlock across each entrance to the enclosure so the enclosure can not be entered without breaking the circuit and removing power. With this arrangement the tester automatically eliminates the hazard when he enters the test enclosure.

If an interlock is to be used as a safety device, steps must be taken to assure that failure of the device to function will not jeopardize the safety of personnel depending upon the device. To fulfill this requirement, performance standards must be established for the interlock and its control circuits. These standards include:

1. "Fail safe" features. Any failure of the interlock mechanism, loss of power, short circuit or malfunction of equipment will cause the circuit to be interrupted.
2. A visible disconnect in the primary power circuit.
3. An arrangement so it is impractical to circumvent the interlock.

An interlock circuit meeting these requirements is shown in Figure 1. Spring-activated or shorting-type interlocks do not meet the requirements.

Isolating the hazards inside an interlocked enclosure will not eliminate electrical hazards unless steps are taken to prevent hazards from being extended outside the enclosure through meter leads and control wiring. The next step is to establish standards for auxiliary equipment used in conjunction with the test setup. Meters, gauges and exposed "live" parts should be protected with the same principles that apply to the equipment under test. A simple method for doing this is shown in Figure 2.

Integrating the so-called human element into the design of test setups and establishing test standards will provide maximum safety in testing operations. The basic principles include:

1. An adequate enclosure to isolate the hazard and accommodate the products.
2. Visible disconnecting devices to remove power from the enclosure.
3. Two flashing red lights to denote the presence of a hazard.
4. Protective interlocks that remember when humans forget.
5. Confining all conductors leaving the enclosure so that no hazard is brought out by auxiliary equipment or measuring devices.

Figure 3 illustrates some of the different types of interlocked enclosures used by the General Electric Company to test a wide variety of products ranging in size from turbine generators to toasters. Each of these enclosures meets the safety standards discussed in the preceding paragraphs, even though details vary to accommodate the product being tested.

IDENTIFICATION: Identification of controls, test enclosures, and other items where knowledge is essential for operation and safety, should be considered in test setup. It is treated separately in this paper to emphasize its value in preventing operators from becoming confused and making mistakes in judgment.

Numerous accidents have resulted from improper power plugging. Investigation of these accidents generally reveals that proper identification on the plug board may have prevented the accident. The reaction of an operator during an emergency or when performing repetitive operations should be anticipated, and allowances factored into the location and identification of controls to minimize mistakes in judgment.

Color coding can be used effectively for ready identification, such as painting controls blue and stop buttons red. Schematic diagrams can be provided on equipment where such knowledge is helpful to safe operation of the equipment. Adequate identification of controls and proper use of signs are good investments providing that the use of colors and signs are standardized and meaningful.

PROPER Operating Sequence: Even though human considerations are factored into the design and installation of electrical equpiment, it may be to no avail unless steps are taken to assure proper sequence of operation. This can be illustrated by a knife switch and breaker combination in series in the same power lines. The breaker is provided to interrupt the circuit, and the switch is used to isolate or change the circuit. This is adequate if the proper sequence is followed and the breaker is opened first. Past records give vivid evidence that unless steps are taken to assure proper sequence of operation, operators will sometimes open the switch first. When a

high voltage power circuit is interrupted with a knife switch the results can be disastrous. It is a worth-while investment to mechanically interlock the knife switch to the "hold in" coil on the breaker so that the knife switch cannot be opened with the breaker in the closed position.

This approach will necessitate proper sequence of operation; however, in some cases it may not be practical, and an alternate method is needed. The alternate method would be the automatic elimination of the hazard in case of improper sequence, such as the use of an electrical interlock on the test enclosure.

The American Standards Association code for the design of a three prong plug is a good example of the steps that can be taken to assure proper sequence of operation. Users of portable electrical tools with a two-prong plug and ground "clip" are instructed to connect the ground clip first, then insert the plug. This safety precaution is frequently violated and the sequence reversed or the ground connection not made at all. Use of a three-prong ASA type plug, with the ground prong longer than the two curent-carrying leads, will assure that the ground connection is made first and proper procedures followed.

Wherever possible the designer should lay out the test setup and select equipment that will assure proper operating sequence. Where this is not possible, methods should be used that will minimize the hazard when proper sequence is not followed. For example:

It is possible and quite probable that a lead connecting power from a plug board to a test may be disconnected in such a manner that one exposed end may be electrically hot. The shock hazard can be reduced by polarizing the plug so that only the male end will fit the plug board (source of power) and the female connected to the test. In case the cable is removed from the test equipment without disconnecting power, then the "live" part will be protected.

FAILURE of Equipment: Even though the functional specification for equipment is met, the user should be aware of the possibility of equipment failure and take precautions to provide adequate equipment and

Fig. 3A—Table top test enclosure, used for testing small light equipment.

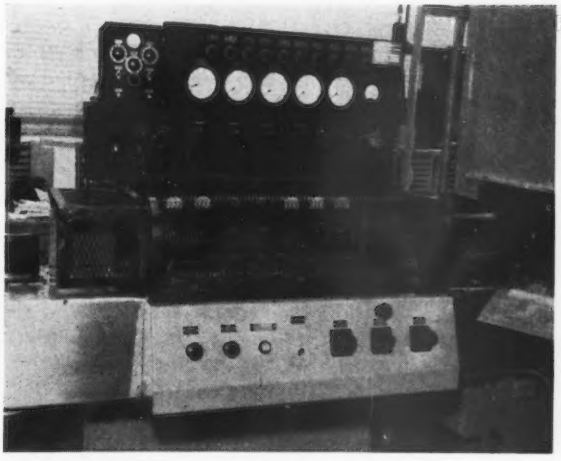


Fig. 3B—Fast conveyor line test enclosure, used for testing small equipment on fast moving conveyor line.

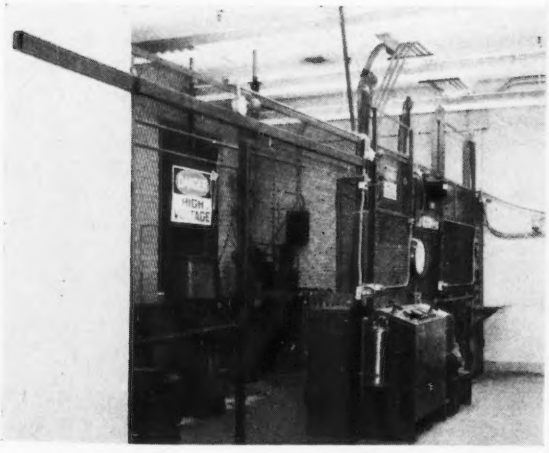


Fig. 3D—Walk-in type test enclosure, used for testing large and/or heavy equipment.

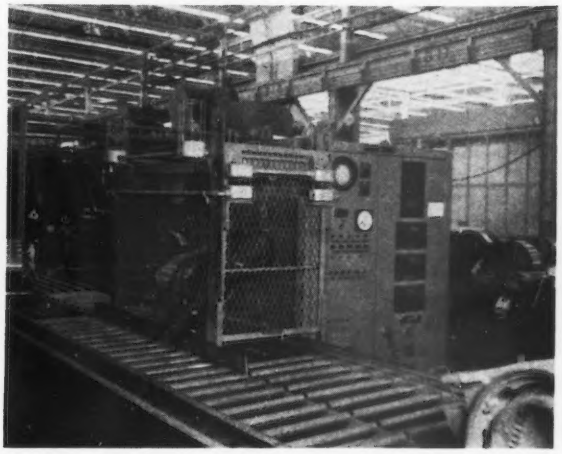


Fig. 3C—Slow conveyor line test enclosure, used for testing heavy equipment on a slow moving or manual conveyor line.

personnel protection in the event of such failure. At a minimum the following protection should be provided for electrical equipment:

1. Over-current devices that will limit the current to a value that can be safely carried by the test equipment and the product being tested.

2. Grounding non-current carrying parts to provide a path for possible fault currents.

3. Automatic circuit-interrupting devices that will disconnect power in case of a failure, such as fuses, circuit breakers or contactors.

4. Under-voltage devices, where needed, such as on the D. C. field on a motor.

It is necessary to take an additional step in cases where there is the possibility that an equipment failure will create a hazard, such as the explosion of a circuit breaker during an over-current test. This will require additional provisions to confine the potential hazard.

CIRCUMVENTING Safety Devices: An analysis of electric shock cases indicates that where it is normal practice to provide interlocked enclosures and standards as outlined in this paper, that many accidents are the result of the operator circumventing the safety device. The principal reasons for this are:

1. Poor judgment on the part of the designer or person doing the circumventing. A specific case in point occurred when a low-voltage test setup for testing breakers was modified for a special test. The voltage in the original test was approximately eight volts and was supplied from a fixed source. In order to accommodate a larger current for a special test, the circuit was changed to obtain 30 volts. A tester made accidental contact with the exposed part of the circuit and was electrocuted. The investigation of the accident revealed that the voltage was obtained through a variac from a 440-volt source, and though there was only 30 volts between terminals, the modification of the circuit made it possible to obtain 440 volts to ground. Lack of good judgment in the modification of this circuit and failure of the supervisor to recognize the hazard effectively built an accident into the test equipment.

2. Inconvenience. If the safety device is inconvenient for the operator to use, the natural tendency will be to circumvent the device. A highly repetitive operation that requires the tester mechanically to activate an interlock for each operation may create a desire on the tester's part to tie the safety device down if he is not keenly aware of the hazards. In making temporary setups, it is a temptation to eliminate or by-pass such items as electrical interlocks because of the time, trouble and expense of putting them into the circuit.

3. Bottleneck. If the enclosure or interlock causes a bottleneck in the production line, it will invite circumventing existing equipment or eliminating the restrictive safety device. A careful study of the method of testing will, in many cases, show that there is a better method of performing the test that is more compatible with the manufacturing operation. (For example, on some high potential testing operations it is possible to limit the test current to less than five milliamps. Currents less than five milliamps are not harmful to the body and elaborate safety devices are not needed. Wherever this is possible, it will expedite the test operations, eliminate the cost of safety devices and provide adequate safety.) The designer has an obligation to study these factors and take them into consideration in the layout of the test setup. This is essential if we are to maintain a set of safety standards that will be compatible with the rapidly changing manufacturing requirements.

FELLOW Employes: The fact that another employe could unknowingly subject the tester to a hazard should also be factored into the safety standards. To prevent a fellow employe from energizing a circuit that would subject personnel working on the equipment to injury, a tag-out procedure should be established. The General Electric Company uses a circular red tag for locking out electrical circuits that, if operated, would subject personnel to injury. It is hung on the primary disconnecting device that controls the power to the equipment. Instructions on the tag prohibit the operation of the switch until the tag is removed by the person who signed the tag.

Establishing a definite procedure to clear electrical circuits before switching power may prevent a person from unknowingly causing an accident. The procedure should require that a check list be established to notify all parties concerned of the action to be taken and the safety precautions necessary to eliminate the hazards.

A procedure should be established to prohibit a person from working alone on a hazardous test. This will assure that a person involved in an accident will have a better chance of survival. A complete set of operating procedures for each test is needed so that all parties involved will be aware of the hazards and know the safe procedure to follow to prevent exposing themselves to hazards or jeopardizing the safety of fellow employes.

CONCLUSION: There should be no fatal electrical accidents in electrical testing operations. The hazards of electricity and its effects on the human body are known and can be controlled.

Analyzing the environment in which the tester operates and his reaction to factors in this environment will provide the vital information needed to satisfy the human requirements. Integrating these human requirements with the functional requirements of the electrical testing operation will provide an equation that will eliminate electrical shock as a source of industrial fatalities.

The answer to this equation is to establish for each test setup:

1. A set of operating procedures that would, if followed, provide adequate safety.

2. A means of identifying and isolating electrical hazards, so that contact cannot be made with a "live" part.

3. Safety devices that will remember when people forget and automatically remove power when a hazard is exposed.

4. "Fail safe" characteristics of the equipment and safety devices so that failure or malfunction will automatically remove power and eliminate the hazard.

This article is condensed from a paper by the authors which was published in Electrical Engineering Magazine, March, 1956.

AMERICAN SOCIETY OF SAFETY ENGINEERS

I am a Safety Engineer. In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

As a Safety Engineer, I will participate in none but honest enterprise. To him that has engaged my services as employer or client, I will give the utmost of performance and fidelity.

When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity, and I accept the challenge that this implies.

Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any Safety Engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession

Since the Age of Stone, human progress has been conditioned by the genius of my professional forbears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble.

I dedicate myself to the instruction of younger members of my profession in all its arts and traditions. To my Fellows, I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity.

AMERICAN SOCIETY OF SAFETY ENGINEERS

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THE American Society of Safety Engineers has established the following classifications of active membership:

MEMBER—To be eligible as a Member an applicant shall be at least thirty years of age and shall be engaged in safety engineering. In addition, he shall have either an engineering or science degree in an accredited college curriculum and the equivalent of eight full years' experience in safety engineering; or he shall have had the equivalent of ten full years' experience in safety engineering.

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